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The Value of Gaseous Disinfectants.

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It is a well known fact that in a large number of diseases substances are thrown off from the body which, if not destroyed, possess the power, under favorable conditions, of infecting some other individual with the disease. These substances differ as to form in different diseases, and in some diseases are much more dangerous than in others.

It should be remembered also that there is a difference between infectious and contagious diseases. Diseases that depend for their existence up-

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on the presence of bacteria in the tissues are known as infectious and the process by which these diseases are caused is known as infection. A contagious disease is one transmissible from individual to individual by immediate or direct contact. Contagious diseases like infectious diseases, are dependent upon active, pathogenic bacteria or protozoa in the tissues. It is evident then that the term infectious, as referring to the causation of dfseases, is broader than the term contagious which relates only to the manner of transmission.

As the term is ordinarily understood infectious diseases, as distinguished from contagious diseases, are spread indirectly; that is, in a round about way, by means of water or food to which the bacteria have gained access; as for example, typhoid fever. While most of the contagious diseases are transmitted in the same way as the infectious diseases, they are also communicated by direct contact from a sick to a healthy individual; as for example, small pox. It is plain then that all contagious diseases are infectious but that many infectious diseases are not contagious. Typhoid fever and cholera are examples of non-contagious, infectious diseases. Erysipelas, pneumonia, tuberculosis, glanders, and diphtheria, though not usually contagious, may become so under favorable conditions. Small pox, measels, scarlatina, mumps, and chicken pox are infectious diseases that are notably contagious.

Many of the bacteria which cause both infectious and contagious diseases are capable of living for a long time outside of the body, and even have the power of increasing when conditions are most favorable. With a view of preventing these bacteria from living and infecting other individuals, disinfectants are used.

Strictly speaking, the term *disinfectant* means a substance capable of destroying infectious agents. But because of the fact that in ordinary disinfection both innocent and infective bacteria are killed, the term *disinfectant* has come to mean the same as the term *germicide,* which means a substance capable of destroying all living bacteria or micro-organisms.

It is well to define here a few other terms, because of the frequent misunderstanding of the meaning of these terms, and of the principle involved, and because of the confusion that arises from their inaccurate use. Briefly, then, a *disinfectant* or *germicide* may be defined as a substance that kills bacteria and their spores; and an *antiseptic* is a substance that interferes with the growth of bacteria without necessarily killing them; while a *deodorizer* may be either a disinfectant, or an antiseptic, or simply a substance having the power of destroying, or masking odors, without regard to either destroying the bacteria that cause them or arresting their development.

It is well to remember that most disinfectants have the property of preventing the development of bacteria, even when less is used than would be

necessary to disinfect; that is, in weaker forms or smaller quantities most disinfectants exhibit antiseptic properties.

Deodorizers are quite another thing from disinfectants. It is true, however, that if a disinfectant or antiseptic is added to undecomposed matter that it will destroy or prevent the growth of the bacteria which cause putrefaction and thus prevent decomposition and the evolution of bad odors. But when decomposition is well advanced there are few, if any, of the trustworthy disinfectants that have the power of completely destroying bad odors. There are, however, many substances which will absorb odors, or mask them by substituting one odor for another. Lime is one of the commonest of those materials which absorb odors. Carbolic acid is often set about the sick room in shallow vessels to purify the air and kill disease germs. The fact is that it kills only the germs in the vessels in which it is placed and no others, and masks to some degree the bad odors in the room. It is absurd to consider that carbolic acid will disinfect a room when used in this way. Experiments in this thesis show that carbolic acid used in the proportion of 500 cubic centimeters to each 1,000 cubic feet of air space must be quickly evaporated in a closed room and the air must be saturated with moisture before even non-spore producing, pathogenic bacteria, such as diphtheria germs, are killed. Even the above results cannot be obtained unless the room is tightly closed and kept so for at least six hours. This shows that carbolic acid as ordinarily used is a deodorizer only. Carbolic acid has considerable value as a disinfectant when the floors and walls are scrubbed with a five per cent solution. Deodorizers are of no value as far as killing germs and preventing diseases are concerned and they may even mask or absorb odors that would otherwise cause uneasiness and be given attention if noticed.

The work reported in this thesis has to do altogether with chemical disinfection where the gaseous form of the compound is used, and the work has been confined in principle to the disinfection of rooms and of material which it is necessary to use around a patient suffering from some infectious disease.

For the purpose of conducting these experiments a box was used having a capacity of about twelve cubic feet. This box was so arranged as to allow the removal of parts of the material experimented with at different times. It was also provided with a thermometer for registering the temperature and a hygrometer for indicating the amount of moisture present in the air. In all of these experiments a corresponding amount of the infected material was kept in the laboratory as a check on the material placed in the disinfecting chamber. At the end of the experiment cultures were made

from the material exposed in the chamber as well as from that kept in the laboratory as a check and from these cultures conclusions were drawn as to the effect of the disinfectant.

In this work use has been made chiefly of the germs of Anthrax and Staphylococcus pyogenes aureus because anthrax germs produce spores and and the aureus goes into a resistant condition in old cultures, so they are practically the hardest of all disease germs to kill. Other germs, such as Typhoid, Prodigiosus, Bacillus Mallei, Streptococcus pyogenes, and Bovisepticus, have been used in connection with these. These germs are of about the same resistance as the germs of Diphtheria and Pneumonia and are less dangerous to handle and are, as a rule, easier to cultivate.

The disinfectants tested were sulphur dioxide, vaporized carbolic acid, and formaldehyde gas. They were tested under different conditions of moisture and temperature and for different lengths of time. From the results obtained by using the above disinfectants in the specially constructed chamber, the quantity of chemical necessary for disinfecting a room of one thousand cubic feet has been calculated and the correctness of these results tested later in a room of twenty-five hundred cubic feet capacity. In the original thesis the results of the experiments are stated in tabular form, there being twenty tables. In this summary of the work it was thought best to give only the general conclusions and results without stating in detail all of the work. In all cases the amount of the disinfectant stated has been calculated as the quantity necessary to disinfect one thousand cubic feet of space.

SULPHUR.

Sulphur dioxide, or the fumes arising from the burning of sulphur, is the oldest gaseous disinfectant and, until recently, the one in common use, and the one considered the best. It has been found in these experiments that even an excessive amount of sulphur can not be depended upon to kill every spore and resistant bacteria in a dry atmostphere and when the material to be disinfected is in a dry condition.

Experiment No. 1.—This experiment shows that five pounds of sulphur burned to each thousand cubic feet of air space will kill all exposed Anthrax germs and also those in one or two folds of heavy towling provided the air saturated with moisture and the temperature of the room is 90° F. or above and the gas is allowed to act for at least four hours. Later experiments show that a great deal larger amount of sulphur when acting in a dry atmostphere for the same length of time will not kill Anthrax spores or resistant pathogenic germs even though they are unprotected. Sulphur is im-

ractical in most room disinfection because the fumes of sulphur will de-
olorize fabrics and attack most metal fixtures about the room, especially
lverwear. Results are very uncertain unless an excessive amount of
oisture is present in the air.

CARBOLIC ACID.

Experiment No. 2.—In this series of experiments, use was made of the apor, or gas, from carbolic acid. The acid was placed in a granite vessel and evaporated over a gas flame. A test was made of carbolic acid because it is such a well known and valuable disinfectant when used in weak olutions, and many think that the vapors of the acid are an effective disinectant as it is frequently used by sprinkling a small amount over the floors. n the actual test of the gas it was found that in a tight room containng one thousand cubic feet of space—an abundance of moisture being presnt and the temperature being 85° F.—that the evaporation of 625 cubic centmeters (about one and one-half pints) of pure carbolic acid would kill the on-spore producing bacteria that are unprotected, provided the room was ept tightly closed for four hours. The results obtained in this test show nat Anthrax germs were not killed after six hours exposure while such erms as the Bovisepticus and Prodigiosus were not killed under two hours' xposure. From the above it is evident that carbolic acid vapor is not to e depended upon as a disinfectant. To be an effective disinfectant, it must e used in solutions having a strength of three to five per cent and must ome into direct contact with the germs.

FORMALDEHYDE OR FORMALIN.

Formaldehyde or *formalin* is a disinfectant of high value for surface disnfection in rooms because it destroys in a very short time, not only the less esistant non-spore forming bacteria, but also the most resistant germs and heir spores. But even it has only slight penetrating power when it comes o disinfecting heavy comforts and matresses and if it is impossible to have hese disinfected by a steam autoclave, they should be burned if they beome infected. It has, however, been found that this gas will penetrate rdinary cotton clothing if hung so that the gas can circulate freely among hem. There are a great many methods of using formaldehyde gas. Very atisfactory results can be obtained by boiling or vaporizing formalin which is a 40 per cent solution of formaldehyde gas in water. Formalin nay be vaporized in the room or this may be done outside in a closed vesel and the gas conducted into the room through a key hole or other opening by means of a rubber or glass tube. Formaldehyde gas has a great ad-

vantage over other disinfectants because it does not act upon metals fabrics although it is very irritating to the eyes and respiratory muc membrane. By using 42 cubic centimeters of formalin per 1,000 cubic of space as good results are obtained as by burning five pounds of sulp under the same conditions of moisture and temperature.

Experiment No. 3.—In beginning these experiments we had very li information at hand as to the amount of formalin to evaporate per cu foot of space in order to secure thorough disinfection. Nearly all of tests in this experiment were made with the idea of determining the m imum amount of formalin required to kill such resistant bacteria as Anth and pyogenes aureus when threads infected with these germs were fully posed to the action of the gas. After a number of tests were made it found that when formalin was evaporated in the proportion of 42 cubic c timeters to 1,000 cubic feet of space with a temperature of 85° F. and ab dant moisture (90 per cent) that all of the different bacteria used in the periment were killed after a six hours' exposure. When thirty-three cu centimeters of the formalin were used under the above conditions all of bacteria were killed except the germs of Anthrax and Staphylococcus aure This effective disinfection was not obtained in a dry atmosphere, the te perature of the room being the same.

As a final test of formalin under practical conditions, a room was lected having about 2,500 cubic feet of space in it. This room is one of bacteriology laboratories at the college and contains the ordinary ap ratus of such a laboratory. It is a reasonably tight room but is no be in this respect than most rooms of good residences. For this experim the temperature of the room was raised to 95° F. and the moisture to per cent as indicated by the hygrometer. The temperature and moisture the room were raised by boiling two or three kettles of water for half hour before starting the experiment. The infected material, which cons ed of infected threads exposed in plates, infected material placed betw two folds of a bath towel, under pieces of carpet, and between pads of ton one inch thick, was placed in the room. Under the above conditi and with the infected material slightly moistened, it was found that vaporizing formalin in the proportion of 240 cubic centimeters to each 1, cubic feet of space that in four hours all of the Anthrax germs were ki that were exposed and also those that were protected by two folds of he toweling; but where they were protected by one inch pads of cotton or ca they were not killed. This test shows that for such bacteria as the typh fever or diphtheria germs, formalin vaporized in the above quantity 1,000 cubic feet of space is a reliable and safe disinfectant. For such

as the Tubercle bacillus at least 300 cubic centimeters of the formalin d be used per 1,000 cubic feet of space, and the room left closed for at six hours, the moisture and temperature conditions being as indicated e.

FORMALDEHYDE CANDLES, OR GENERATORS

The commercial article known as *formaldehyde candles,* or *generators,* which nd at almost every drug store was tested also. The same room as in bove experiment was used, and had the same conditions of moisture emperature. The directions that were given on the candle were follow- nd it was found that the candles would kill, when used in the propor- of one candle to 1,200 cubic feet of space, all unprotected germs—in words, all germs on the surface—but had no effect on germs protected oth, etc.

n conclusion we would say that disinfection must be complete, every must be killed. That is the most important thing to be remembered be- e a partial disinfection is, in practical use, worse than no disinfection use as long as any pathogenic germs remain alive the room is still erous and if it has been disinfected a person puts confidence in that and uses no precautions, while if a person knows that the room is erous or has not been disinfected, care will be taken. Therefore, in a person has a contagious or infectious disease, all unnecessary arti- of furniture should be removed from the room. The carpet should be ved, and all drapery except that made of thin cotton material which e easily disinfected. The bed should be furnished with thin cotton rs that can be boiled when soiled, or when the patient has recovered. n preparing to disinfect a room put every article of clothing and bed- that can be boiled into a boiler of hot water before removing them from oom, or where possible send them to a steam autoclave. If it is impos- , all of the heavy articles about the bed should be burned because they ot be satisfactorily disinfected as shown by these experiments. The ining articles should be hung on lines drawn across the room in such y that not more than one or two thicknesses of the cloth will be together. all cracks and openings in the room should be closed by pasting pa- ver them. The cracks in the windows and doors should be stuffed with r or rags. Then the room should be closed and the temperature raised dy heat and the moisture to 90 per cent. It should be always remem- l that the more moisture in the air and the more heat, the more perfect esults, no matter what gaseous disinfectant is used. After this is done an atomizer or in some other way sprinkle the floor and walls and

any cloth that is to be disinfected. The room is then ready to be disinfected, and it would be well to get a reliable formaldehyde machine, but if this is impossible, about 240 cubic centimeters of formalin vaporized to each 1,000 cubic feet of space will answer. It has been found that this amount is safest when clothing or other articles are to be disinfected in the room. The formalin may be boiled on a stove, if one is in the room, or over a lamp or gas jet. Care should be taken to avoid danger from fire. The room should be left closed four hours after the formalin has begun to boil. When the four hours have past the room should be opened and aired well. If ammonia water is sprinkled about the room or set in open vessels it will help to destroy the odor of formaldehyde. As soon as the gas is all out of the room, it is ready to be occupied again.